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Solventless Bore Cleaning System for the M256 Tank Cannon

by Mark Bundy, Julius Pitts, Robert Baylor, Jerry Doss, and Calvin Karschner

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14. ABSTRACT
Bore cleaning is an essential part of gun barrel maintenance. The technical manual for the Abrams tank gun barrel calls for bore cleaning to occur after every firing exercise. Standard practice at a military proving ground, such as Aberdeen Proving Ground, MD, is to clean the barrel after every firing “program,” perhaps 5–10 cleanings per barrel per year, 250 total cleanings per year. The degree to which a barrel is considered clean varies. Proving-ground barrels are usually cleaned to higher standards than those in the field. However, proving-ground cleaning is machine-powered (vs. manually done in the field) and is usually, if not always, done in preparation for a detailed bore wear/damage inspection. The proving-ground cleaning process typically involves a motorized cleaning brush (metal) in the presence of a cleaning solution and usually takes three men 60 min to bring a bore to wear-inspection standards. This report describes a new solventless bore cleaning technique, which uses silicon-carbide-grit impregnated on a nylon bristle brush to clean the bore in roughly 1/3 the time, with half the personnel, using less expendables, at 1/4 the cost. Testing shows that the new cleaning method does not damage the chrome plating nor the metal substrate where chrome is missing as a result of firing-induced damage.

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1. Introduction

The U.S. Army Technical Manual (TM) 9-2350-264-20-2-1[1] calls for the M256 barrel on the Abrams tank to be cleaned "after firing and the day after firing," as well as semiannually. Field cleaning of the Abrams tank barrel is a manual process, done with tank-stored equipment (pole, brush, cleaning lubricant, and preservative, CLP), as described in TM 9-2350-388-10-2.[2] Naturally, the level of bore cleaning that can be achieved "by hand" cannot compare with mechanized bore cleaning equipment such as that available at proving grounds like the U.S. Army Test Center (ATC) at Aberdeen Proving Ground (APG), MD, where barrels are cleaned and inspected after every firing program. The scope of this report is limited to a comparison between the current mechanized bore cleaning procedure used at ATC to clean stand-alone barrels (separated from the Abrams tank) and that of a new mechanized approach that can be done either in the stand-alone mode or with the barrel tank-mounted.

2. Traditional Proving-Ground Bore Cleaning

The traditional method for cleaning the 120-mm (4.72-in) M256 Abrams tank gun barrel at ATC is to use a slightly bore-oversized commercially-sold steel brush (~152-mm [6-in] diameter, costing ~$20) (figure 1a). The brush is attached to the end of a rigid metal pole (figure 1b) that is slightly longer than the barrel (~23 ft). The brushless end of the pole is connected to a drill-like (~3/4 hp, pneumatic) motor (figure 1c) which is supported on a stable, but mobile platform (figure 1d). Experience has shown that the traditional steel brush cleaning process is accelerated by lubricating (with ~2 qt per barrel cleaning) the steel brush bristles with CLP (stock number 9150-01-053-6688) or with cleaning compound rifle bore cleaner (stock number 6850-00-224-6663). A solvent catch-basin is positioned at the muzzle end of the barrel when the brush is pushed-pulled from the breech end.

Most APG barrels require ~60 min to clean, with one person pushing the motor, one person guiding/supporting the pole, and one person lubricating the brush after every up-and-back cycle (figure 2).[*] Typically, a steel brush will clean 1–2 barrels before it needs to be replaced.

[1]Department of the Army. *Unit Maintenance Manual Vol 1 of 4 for Tank, Combat, Full-Tracked: 120-mm gun, M1A1.* TM 9-2350-264-20-2-1; 2003, 2–29, 2–104.

[2]Department of the Army. *Operator's Manual Unusual Conditions, Troubleshooting, and Maintenance Vol 2 of 2, Tank, Combat, Full-Tracked: 120-mm gun, M1A2 System Enhancement Package (SEP).* TM 9-2350-388-10-2, July 2000, 3–168—3–171.

[*]In some rare cases, cleaning can take several hours if firing-deposited residues are particularly resistant to the scrubbing action of the solvent and brush.

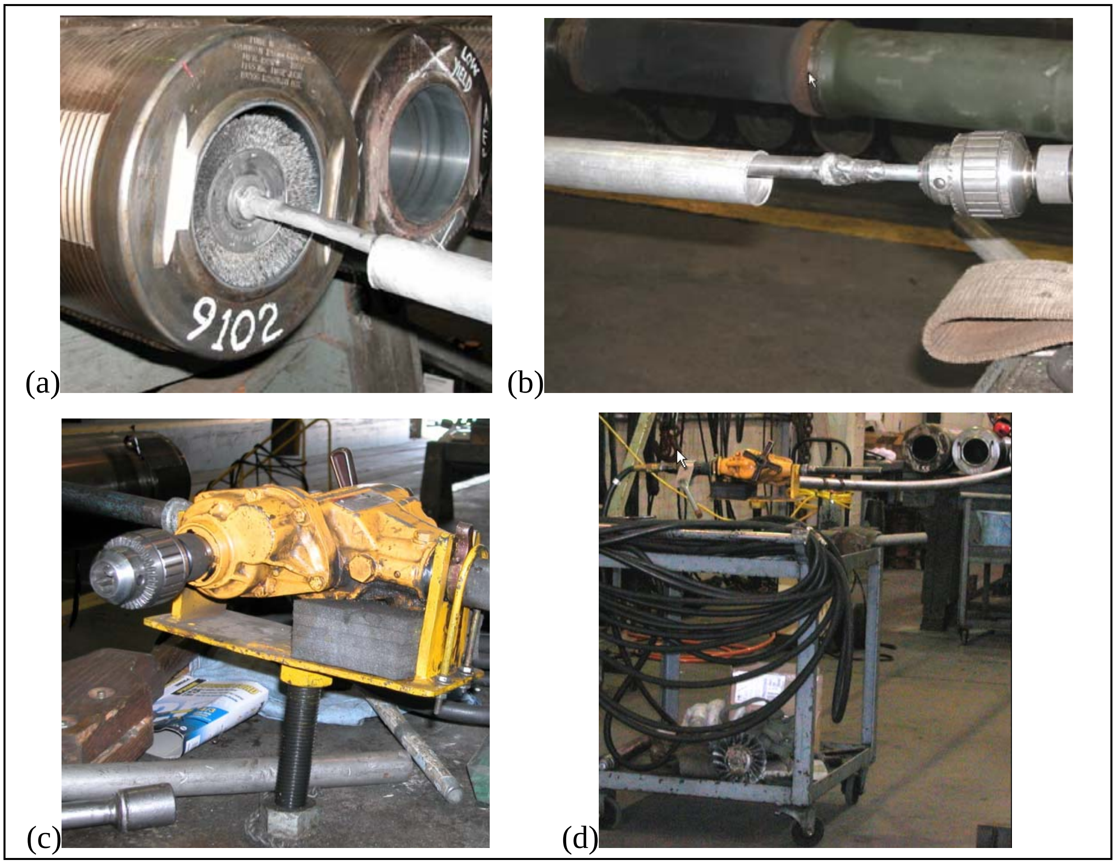

Figure 1. Traditional mechanized bore cleaning (a) brush, (b) pole, (c) pneumatic motor, and (d) cart for supporting translation of motorized brush system up and down the bore.

3. New Bore Cleaning Approach

Like the traditional system the new approach uses a rotary brush. However, the brush is organic, as opposed to metal, and the rigid rotating pole is replaced by a flexible steel cable, spinning inside a flexible steel casing. The new system is commercially sold by GI Industries, CT (who manufacture industrial duct and pipe cleaning systems).[*] The GI gun barrel brush "head" comes in two configurations: a slightly bore-oversized (122-mm diameter) cylindrical array of silcon-carbide-impregnanted (120 or 180 grit) resin-matrix spheres attached to the end of nylon bristles radiating from a steel center-shaft (costing ~$160) (figure 3a), or the brush head is configurable as a loose, mop-like (swab) collection of silicon-carbide-impregnated nylon strands

[*]Mr. Joseph McDeshen, Chief Artillery Supervisor, ATC, APG, MD, was the first to recognize that the GI brush system might be useful for cleaning the M256 gun barrel.

Figure 2. Traditional three-person mechanized bore cleaning procedure for the M256 barrel.

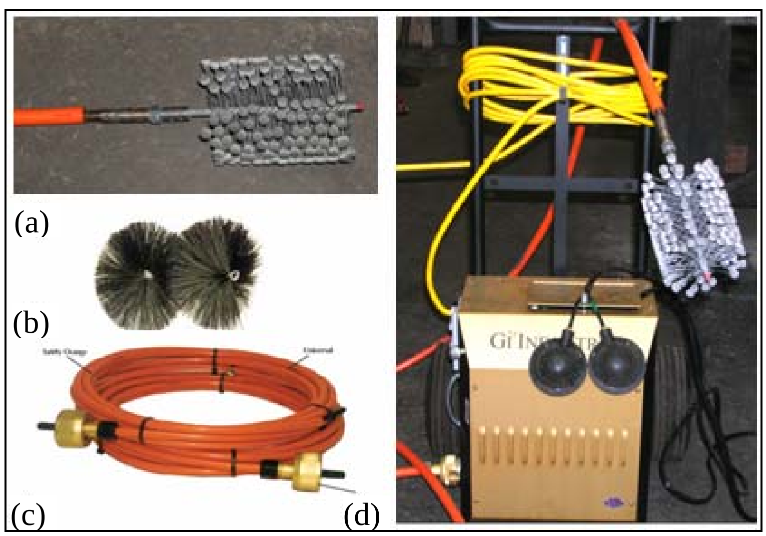

Figure 3. GI industries bore cleaning (a) ball brush, (b) swab brush, (c) flexible steel drive shaft, and (d) foot-peddle-controlled electric drive motor.

(~250 mm in length) emerging from a steel center-shaft (costing ~$50) (figure 3b). The center-shaft has a threaded coupling for attachment to the flexible steel drive-shaft (figure 3c). The drive-shaft cable is spun by a (1/2 hp, electric) motor, contained in a ruggedized, portable cabinet, operated by foot-peddle controls (figure 3d).

Forward and reverse foot-peddle options allow the brush operator, typically standing at the breech end of the barrel, to control the spinning direction of the brush head and facilitate pushing or pulling (respectively) the brush up and down the length of the gun bore (figure 4). As will be shown in the results section, the GI brush system of figure 4 works well without using a supplemental cleaning solution. Dust generated from removed propellant residue and eroded brush material (silicon-carbide/resin matrix) can be continuously removed from the gun bore through a vacuum filtration system (not shown here). Although one person can operate the GI brush system, a second person may be useful to ensure the cable coils and uncoils freely as the brush moves up and back in the barrel. As will be discussed, the new brush can clean a barrel in 20 min or less (including equipment preparation and brushing time), with each brush cleaning an estimated 8–16 gun barrels before it needs to be replaced.*

Figure 4. One-person bore cleaning procedure for the M256 barrel, using a mechanized GI industries brush system.

*Initial ATC tests have shown that eight barrels can be cleaned with a 180-grit silicon-carbide brush, and preliminary indications are that significantly more barrels/brush can be cleaned if 120-grit is used (awaiting confirmation tests).

4. GI Brush Bore-Wear Check

To ensure that the GI brush would not damage an in-service, high-value barrel by removing its chrome or eroding the exposed steel where chrome is missing, the brush was first tested on scrap sections of M256 tube. Two sections of tube were selected for testing (figure 5); the chrome condition in one tube section was (visibly) faultless, while the other section of tube had large sections of missing/stripped chrome, exposing the underlying base metal. Prior to GI brushing, the bore diameters in each tube sections were measured with a “star” (vernier calliper-type) gauge (figure 5), thereby providing a baseline to evaluate subsequent brush erosion, if any. The wear-test schedule/plan for GI brushing of the two scrap barrel sections is detailed in table 1.

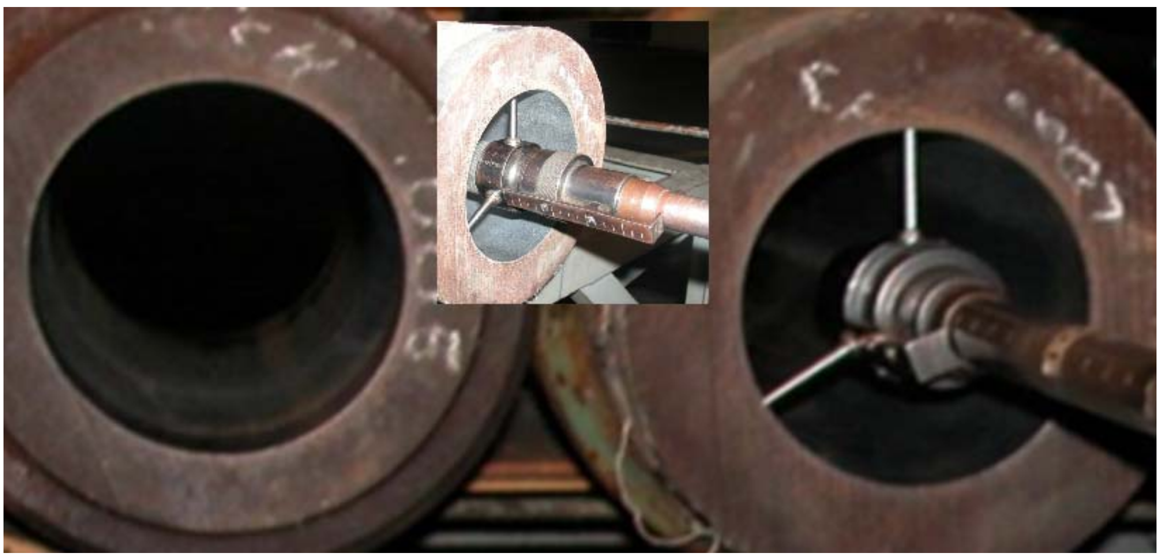

Figure 5. Star-gauging scrap sections of the M256 barrel.

Table 1. GI brush test matrix on scrap barrel sections.

Brushing Trials (120-Grit Brushings)	**Section 1 (Undamaged Chrome)**	**Section 2 (Damaged Chrome)**
(1) 15 min dry	Measure bore diameter	Measure bore diameter
(2) 30 min dry	Measure bore diameter	Measure bore diameter
(3) 60 min dry	Measure bore diameter	Measure bore diameter
(4) 15 min wet (H_20)	Measure bore diameter	Measure bore diameter
(5) 30 min wet	Measure bore diameter	Measure bore diameter
(6) 60 min wet	Measure bore diameter	Measure bore diameter

Figure 6 shows the continuous localized brushing set-up associated with the wear test of table 1. In particular, the GI brush is held fixed, so that the same localized region of the scrap tube sections (one GI-brush-length long) are continuously exposed to the brushing action for the entire test time of each trial.*

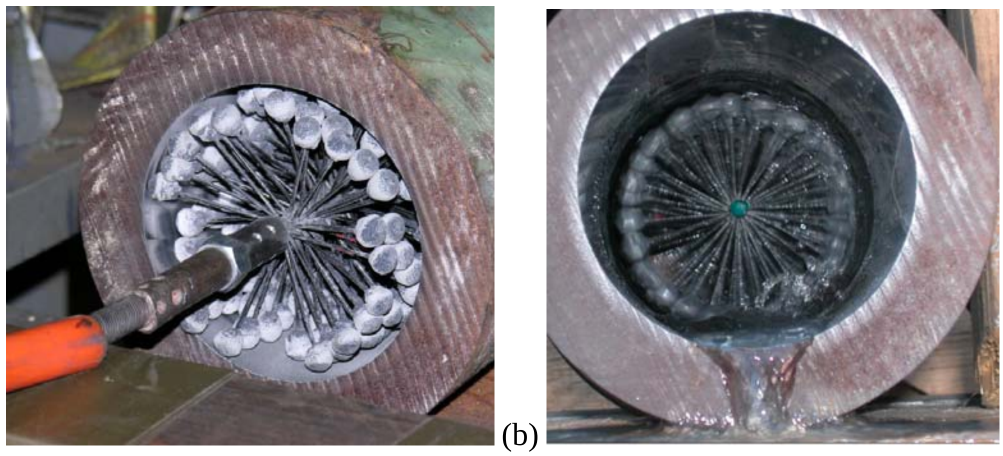

Figure 6. Continuous (a) dry- and (b) wet-brushing set-up for the test of table 1.

The first three dry bore-brushing trials in table 1 were designed to establish surface wear rates, if any. However, no measurable bore diameter change accumulated in the region brushed in either section after 105 min of total dry brushing (over trials 1–3). Figures 7a and 7b show the qualitative appearance of the bore surfaces after trial 3 in both tube sections 1 and 2, respectively. Particularly reassuring in this phase of the GI brush test is the fact that no measurable wear occurred over the substantial areas (of axial and circumferential extent) where chrome-stripped steel was exposed to the brush (in scrap barrel section 2 [figure 7b]).

As stated earlier, and will be discussed in the next section, the entire barrel (bore and chamber) surface can be cleaned in ~15 min, or less, of back and forth motion. Based on the fact that the bore brush is ~100 mm in length, and the overall barrel is 5300 mm in length, the barrel can be viewed as ~53 brush-lengths long. Theoretically then, each of the envisioned 53-barrel sections is exposed to a brushing action time of ~15 min/53 sections = ~17 s/section during a typical barrel cleaning. Thus, 105 min of brushing in the same section, as done over trials 1–3 of table 1, without any measurable wear, is the equivalent of what any given barrel section would be subjected to in ~370 barrel cleanings (6300 s [= 105 min]/~17s), probably more than would accumulate in a typical "barrel life."

*In this phase of testing, a slightly bore-undersized (~100 mm diameter) brush was used, brushing primarily the chrome and exposed steel (where chrome was missing) over the lower half of the barrel sections.

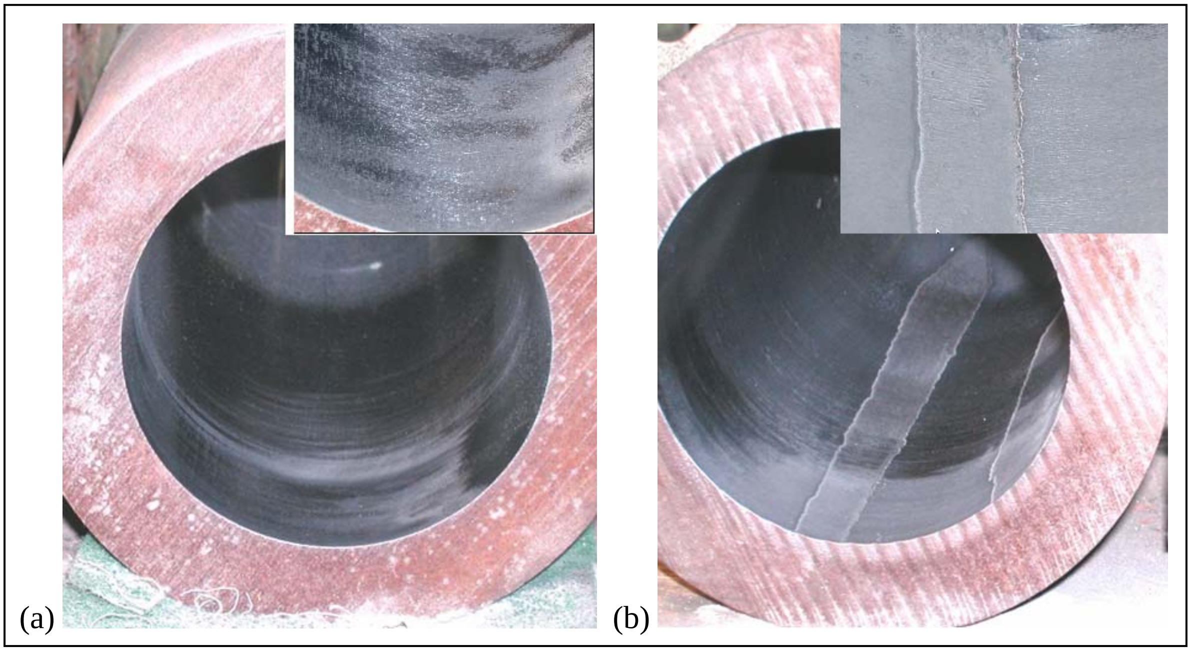

Figure 7. Bore surface appearance after 105 min of dry GI brushing in (a) undamaged chrome and (b) chrome-stripped barrel sections.

The purpose of the wet GI brush test (trials 4–6 of table 1, and figure 6b) was to see how much, if any, wear would occur when brushing action is augmented by the paste-like compound that is created when silicon-carbide dust is mixed with water. It was thought, a priori, that such a wet mix might provide "better" cleaning action, but it was not known whether it would accelerate bore wear.

The wet brush effects were investigated on the opposite ends of the two dry-brushed barrel sections. As was the case with the dry brush tests, there was no cumulative bore wear, either to the chrome or to the exposed steel, after a total 105 min of wet brushing (trials 4–6).

With regard to the rank of cleaning, there was no visible difference in the cleaning appearance after 15 min of dry or wet brushing (trial 1 vs. 4), as shown in figure 8a vs. 8b, respectively. However, as already indicated (based on post table 1 testing of a full-barrel length, done after it was determined that the GI brush would not damage an in-service barrel), it was found that a tube is acceptably clean after ~17 s of dry cleaning in each brush-length section of tube. Thus, in testing hindsight, it would be impossible to discern a cleaning difference after 15 min (900 s) of dry or wet brushing of the same single brush-length section of tube, as both brushing conditions would have achieved their maximum cleaning effect well before the end of 15 min.

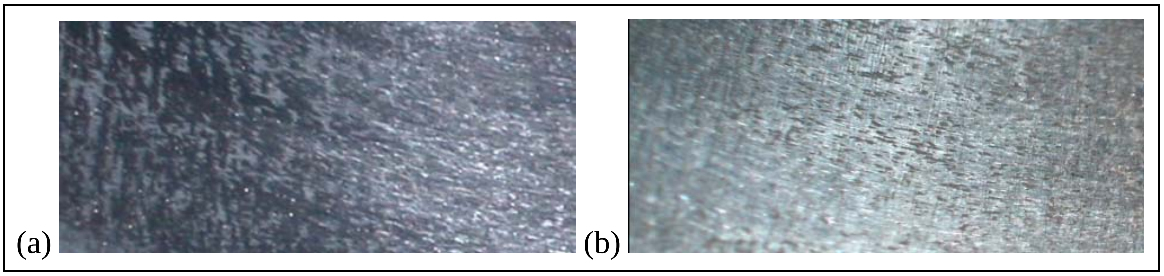

Figure 8. Bore surface appearance after 15 min of localized (a) dry and (b) wet GI brushing.

5. Side-by-Side Full-Barrel Comparison of Traditional vs. New Bore Cleaning Systems

Having established from the testing trials of table 1 that the GI brush (dry or wet) will not damage either the chrome or the exposed steel (where chrome is missing) in the scrap M256 barrel sections, the next step was to determine how well/long it would take the GI brush to clean a full-length, in-service barrel in comparison to the traditional steel brush cleaning process.

Four M256 barrels were identified that needed cleaning, each, more or less, equally “dirty.” The approach was to perform eight full-barrel-length traversals in a dirty barrel with each brush, then examine the bore for cleanness, and repeat if necessary until clean. In this test, a 122-mm, 180-grit GI brush, spun at 200 rpm, was used.*

Both the GI- and steel-brushed tubes are swabbed over their full bore length with a solvent sprayed rag (“punched-out”) prior to being examined for their level of cleanliness by the NonDestructive Test (NDT) team at ATC (who are charged with deciding when a tube is clean enough for subsequent bore inspections). The NDT team at ATC uses an optical bore scope to judge the barrel’s level of cleanliness. A video camera, 1.5 magnification, is also available for use by the ATC NDT team should testing dictate that the bore appearance be documented (for record on compact disk).

After the first eight barrel-length passes (four up and four back) in two dirty barrels, the NDT team deemed the GI-brushed barrels were clean enough to proceed with any post cleaning bore wear examination. The eight passes took the operator ~15 min to complete. Likewise, eight passes with the traditional steel brushing method left the barrel clean enough to inspect; however, eight passes took 30 min to complete.† For example, figures 9a and 9b show the

*It should be noted that in the wear test of table 1, a 100-mm, 120-grit silicon-carbide brush was used for all six trials, a total of 420 min of brushing. However, to clean the full-length barrel, it was decided that a slightly bore-oversized brush should be used, and the only one available at ATC (at the time) was a 180-grit.

†Pushing and pulling the 152-mm diameter steel brush through a 120-mm bore diameter requires more physical exertion (and therefore takes longer) than the same operation done with a 122-mm nylon bristle brush.

videoed bore appearance (near the muzzle) after the eight barrel-length passes with the GI brush vs. the steel brush, respectively. Although both barrels were considered acceptably clean for any subsequent bore wear inspection procedure, the NDT team subjectively judged the GI-brushed surface slightly "superior," having a finer-polished appearance.

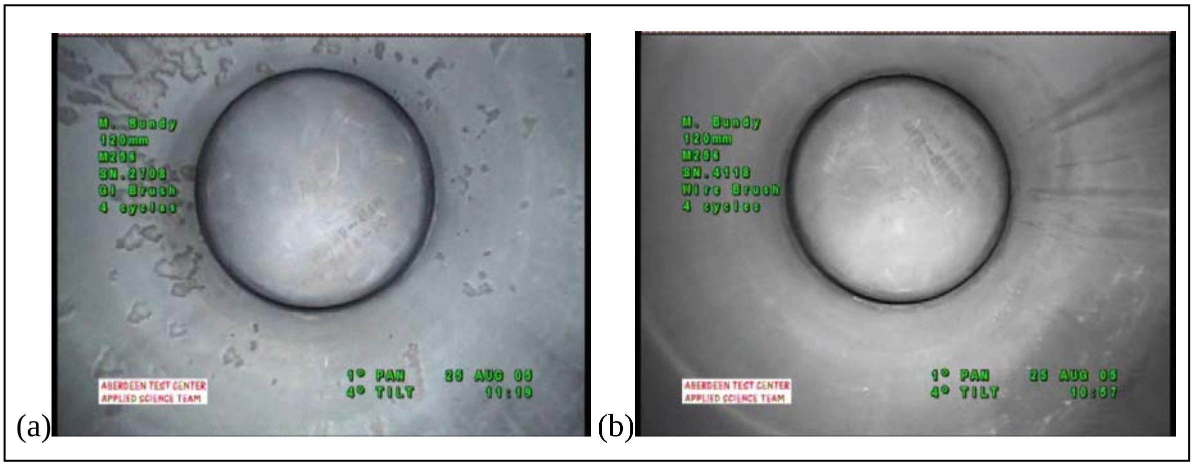

Figure 9. Video image of typical bore surface appearance after full-length barrel cleaning taking (a) 15 min with the GI brush vs. (b) 30 min with the traditional steel brush.

It should be noted that the swab configuration of the GI brush (figure 3b) was utilized to accommodate surface cleaning of the inner-diameter change that exists in going from the chamber to the bore (through the so-called forcing cone) region of the barrel. The strands of the swab-type brush are centrifugally forced into contact with the barrel wall by the rotating brush head. Though no extensive testing was done to compare swab- vs. ball-type brushing in the bore region, it was subjectively felt that the more rigid ball-type brush would be the more efficient method for cleaning (the constant diameter) bore region of the barrel.

Although the actual brushing time to clean the M256 barrel with the GI brush was determined to be 15 min, it is estimated that another 5 min should be allocated to set up, or move, the GI brush system (figure 4) for each barrel cleaning operation, as well as time to punch out the barrel in preparation for subsequent examination.

In addition to the 30-min needed to clean a barrel with the steel brush, ~30 min must be allocated for setup, or moving, of the steel brush system (figure 2) including time to acquire and dispose of the cleaning solution.

Because the steel brushing process utilizes a cleaning solution, it is not as easily adapted as the dry GI brushing procedure to cleaning a tank-mounted barrel.*

*GI Industries makes a vacuum adapter that removes cleaning residue from the brush-inserted end of the tube (gun muzzle) if desired.

6. Summary

Testing of the new GI brush cleaning system, shown in figure 3 and 4, has proven that it can clean an M256 barrel in roughly one-third the time: 20 vs. 60 min, broken down into 15 min vs. 30 min of actual brushing time and 5 min vs. 30 min of cleaning set-up time for the two procedures, respectively.*

Only one person is needed in the dry GI brushing process (as done in this testing), though a second individual may ensure that the cable does not bind and assist in the post-brushing punch-out process. Three people are used with the traditional steel brushing procedure.

The only solvent that is needed with dry GI brushing procedure is that applied to the cloth or rag (or cloth GI swab) used in the post-brushing punch-out phase; whereas, with the steel brushing process, both a cleaning solution and the punch-out solvent are utilized. Dust from the dry GI brushing procedure is collected in a bag and vacuumed from the barrel through a suction hose, while the cleaning solution generated with the steel brushing procedure is gravity drained from a slightly tilted barrel into a catch basin and disposed of later.

Initial tests have shown that a 122-mm, 180-grit GI brush will clean ~8 barrels; however, based on the longevity of the 100-mm, 120-grit GI brush in the wear test, it is expected that future testing will show as many as 16 barrels or more can be cleaned with a 122-mm, 120-grit brush. Years of testing have shown that the conventional steel brush lasts between one and two barrels before it is worn out.

The initial cost of the GI brush (motor and cable) and vacuum system is ~$4–5K, whereas the cost of a steel brush system (motor, drive shaft, cart, catch basin) is ~$2K. The recurring cost of replacing brushes can estimated as ~$160 brush/12 barrels = ~ $14/barrel for the GI brush and ~$20 brush/1.5 barrels = ~$15/barrel for the steel brush. The vacuum bag replacement cost is estimated to be (for a HEPA filtration system) ~$200 five-filter package/100 barrel cleanings = ~$2/barrel. The cost of the cleaning fluid for the steel brushing procedure along with the cost of its disposal is ~$10/barrel. The labor cost for the GI brush, depending on whether one or two people are used and assuming 1.5 people are used for the average 20 min cleaning at $50/hr, equates to ~$25/barrel. For the steel brush procedure, three people working one hour each amounts to $150/barrel. Table 2 shows the estimated recurring cost comparison between the two systems.

*Subsequent testing of the GI brush showed that it can adequately clean a barrel, to wear inspection standards, in 10 min of brushing time.

Table 2. Recurring cost breakdown of bore cleaning procedures.

Category	**GI Brush Method ($)**	**Steel Brush Method ($)**
Brush cost/barrel	14	15
Non-brush materials	2	10
Labor	25	150
Total	41	175

In total, the recurring barrel cleaning cost using the GI brush system adds up to ~$41(= ~$14 + ~$2 + ~$25)/barrel, whereas the cost per cleaning using the current system is ~$175(= ~$15 + ~$10 + ~$150)/barrel. Thus, the maximum difference in initial system cost, $3K, is recouped after ~22 (= ~$3,000/[$175/barrel –$41/barrel]) barrel cleanings.

Assuming ~250 barrels are cleaned annually by ATC, they could eventually net a yearly savings, and/or added income (through reassigned labor), of ~$33,500 (= ~250 barrels × [$175/barrel –$41/barrel]) by changing from the steel to the GI brushing procedure.

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